11/12/99 jc714 U.S. PTO

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: JUNG, et al.

Docket: 9983.97US01

Title: METHOD FOR CONTROLLING TRANSMISSION CONTROL PROTOCOL WINDOW SIZE IN ASYNCHRONOUS TRANSFER MODE NETWORK

jc688 U.S. PTO 09/439206 11/12/99

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- ☒ Utility Patent Application: Spec. 12 pgs; 7 claims; Abstract 1 pgs. The fee has been calculated as shown below in the 'Claims as Filed' table.
- ☒ 2 sheets of formal drawings
- ☒ Certified copy of a Korea application, Serial No. 1999–17310, filed May 14, 1999, the right of priority of which is claimed under 35 U.S.C. 119
- ☒ A signed Combined Declaration and Power of Attorney
- ☒ Assignment of the invention to Korea Telecommunication Authority, Recordation Form Cover Sheet
- ☒ A check in the amount of $760.00 to cover the Filing Fee
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CLAIMS AS FILED

Number of Claims Filed		In Excess of:		Number Extra		Rate		Fee
Basic Filing Fee								$760.00
Total Claims								
7	–	20	=	0	x	18.00	=	$0.00
Independent Claims								
2	–	3	=	0	x	78.00	=	$0.00
MULTIPLE DEPENDENT CLAIM FEE								$0.00
TOTAL FILING FEE								$760.00

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METHOD FOR CONTROLLING TRANSMISSION CONTROL PROTOCOL WINDOW SIZE IN ASYNCHRONOUS TRANSFER MODE NETWORK

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a method for controlling a transmission control protocol (hereinafter, referred to as 'TCP') window size in an asynchronous transfer mode (hereinafter, referred to as 'ATM') network, and in particular to a method for determining a TCP congestion window size by using an explicit rate (hereinafter, referred to as 'ER') value in a resource management (hereinafter, referred to as 'RM') cell.

Description of the Background Art

In general, an available bit rate ABR service has been developed to support a data application in the ATM network, and the TCP is the most widely-used transport level protocol in a currently-used data network.

A TCP window-based flow control is a method for predicting a packet loss by employing an acknowledgement (ACK) signal transmitted from a receiving side. The aforementioned method can detect a congestion state of the network only when the packet loss is generated. Sometimes, the retransmission may be unnecessarily performed by mistakenly predicting the packet loss.

Here, a method for predicting the packet loss detects the congestion state of the network by predicting the packet loss by using a TCP timeout. However, this method has a disadvantage in that a degree of the congestion state of the network cannot be measured because a feedback of the TCP is provided merely by the receiving side TCP.

As described above, the TCP window-based flow control predicts the packet loss, and thus increases/decreases the window size. However, the congestion state of the network cannot be precisely evaluated by a simple increase/decrease of the window size. Accordingly, the window size may exceed an allowable size in the network. At this time, the packet loss and the resultant retransmission are generated, and thus the increase/decrease of the window size and retransmission are repeated.

In addition, since a delay sharply varies according to the network state on the TCP over the ABR service, a retransmission timeout (hereinafter, referred to as 'RTO') value also increases. In case the packet loss is generated, the loss may be detected after the RTO. As a result, the level of performance ability considerably reduces. According to the fast-retransmission algorithm of the TCP-Reno ("TCP/IP Illustrated Volume 1: The Protocols" by W. Richard Stevens (Addison-Wesley, 1994), more than a half of the packet loss can be detected before the RTO, and according to the method suggested by the TCP-Vegas (Lawrence S. Brakmo and Sean W. O'Malley, "TCP Vegas: New Techniques for Congestion Detection and Avoidance, "SIGCOMM '94 Conference on Communications Architectures and Protocols, pp.24-35, Oct. 1994), more than a half of the residual packet loss can be detected in advance, thereby reducing the number of cases of waiting the RTO. Nevertheless, the decrease and recovery of the window size resulting from the retransmission reduce a TCP throughput.

In the conventional TCP over the ABR service, a bandwidth which can be used by the TCP is dependent upon time. Accordingly, a fast recovery to the bandwidth and transmission by a linear increase from the time are not significant.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a method for controlling a transmission control protocol (TCP) window size in an asynchronous transfer mode (ATM) network by employing resource management (RM) cell information of an available bit rate (ABR) service.

In order to achieve the above-described object of the present invention, there is provided a method for computing a window size by using congestion information of a network during data transmission from a transmitting side ATM terminal to a receiving side ATM terminal, an explicit rate value in a resource management (RM) cell being used as the congestion information.

In addition, in order to achieve the above-described object of the present invention, there is provided a method for controlling a transmission control protocol window size in an asynchronous transfer mode network, including: a step for an ATM transmitting terminal to receive a resource management (RM) cell; a step for transmitting an explicit rate value in the received resource management (RM) cell to a transmission control protocol (TCP) level in the ATM transmitting terminal; a step for setting a congestion window to be '1' when the explicit rate value is received; a step for computing the congestion window, when an acknowledgment signal is received from an ATM receiving terminal; and a step for computing a window size, when the congestion window value is computed, and for transmitting a data to the ATM receiving terminal according to the computed size.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become better understood with

reference to the accompanying drawings which are given only by way of illustration and thus are not limitative of the present invention, wherein:

Figure 1 is a schematic block diagram illustrating a network constitution for providing a transmission control protocol over an available bit rate service which the present invention adapts to; and

Figure 2 is a flowchart showing sequential steps of a control process for a window size on the transmission control protocol in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A method for controlling a transmission control protocol (TCP) window size in an asynchronous transfer mode (ATM) network in accordance with a preferred embodiment of the present invention will now be described in detail with reference to the accompanying drawings.

An algorithm according to the present invention is an explicit rate (ER) mode available bit rate (ABR) switch algorithm.

An ER field in a resource management (RM) cell used by the ABR stores a minimum value of throughputs which each node of the network can receive, and returns to a transmitting side. When the ER value is transmitted to a TCP level, the TCP can detect a state of the network before the packet loss, and prepare for the packet loss, thereby improving the performance of the TCP.

To use the ER value guarantees fairness and stability of each ATM virtual circuit, and thus guarantees fairness and stability of each TCP connection.

The TCP window size control algorithm in accordance with the present invention will now be described.

-ATM level transformation of the transmitting side terminal.

When the RM cell is received, the ER value in the RM cell is transmitted to the TCP.

-TCP level transformation of the transmitting side terminal.

The TCP transmitting side sets the following relationship in every acknowledgment (ACK) signal.

$$\text{awnd} = \text{MIN}\ [\text{credit},\ \text{cwnd}] \qquad (1)$$

Here, 'awnd' implies an allowed window, 'credit' implies an amount of data which the TCP receiving side can receive, and 'cwnd' implies a congestion window, respectively.

At this time, a value of 'cwnd' is determined by mapping the ER value and preceding 'cwnd' value, different from the conventional method for controlling the TCP window size.

The mapping enables the TCP transmitting side to determine an optimal window size, thus preventing congestion of the network. In addition, it is possible to efficiently use the bandwidth which can be provided to a given TCP connection.

'cwnd' which is the TCP congestion window size is determined by the mapping, as follows. Firstly, a throughput of the TCP level is computed by the following Expression.

$$\text{TCP throughput} = \text{last\_ER} * \frac{48}{53} * \frac{31}{32} * \frac{TCP\_MSS}{TCP\_MSS + 56bytes} \qquad (2)$$

Here, 'TCP_MSS' implies a maximum segment size of the TCP level. When overheads of the ATM cell, the RM cell, the TCP, the internet protocol (IP), the ATM adaptation layer 5 (AAL5) and an internet engineering task force request for comments 1577 (RFC 1577) are removed from the 'last_ER' value, the bandwidth which can be used by the connection over the ABR, the throughput of the TCP level is computed.

$$\text{cwnd} = \text{TCP throughput} * \text{estimated\_RTT} * \text{safety\_factor} \qquad (3)$$

Here, 'estimated_RTT' is an estimated round trip time, and 'safety_factor' is a numerical value compensating for variations in the network state and RTT.

The computed value is multiplied by an appropriate saftey_factor(s<1), and thus a sharp variation of the network state and influence of the incorrect RTT are compensated, thereby controlling the throughput of the TCP level. The retransmission mechanism of the conventional TCP is used as a retransmission mechanism.

Figure 1 is a constitutional diagram illustrating the TCP service over the ABR service to which the present invention adapts, and shows feedback control loops of the TCP level and the ATM level.

The ATM level 121 of the ATM transmitting terminal 12 consecutively receives the RM cell which returns through the network. The ER value of the RM cell is transmitted to the TCP level 122 of the ATM transmitting terminal 12 as it is. The TCP level 122 of the ATM transmitting terminal 12 receiving the ER value computes the allowed window size (awnd), as shown in Expression (1), by using the congestion window size (cwnd) decided by the ER value and 'credit' which is the feedback control loop information of the TCP level.

As depicted In Figure 1, reference numerals 11, 131 and 132 denote an ATM switch, an ATM level of the ATM receiving terminal 13, and a TCP level thereof, respectively.

Figure 2 is a flowchart showing the method for controlling the TCP window size in accordance with the present invention, and shows sequential steps of the information transmission between the ATM level 121 and the TCP level 122 of the ATM transmitting terminal 12, and the computation of the allowed window size (awnd).

Firstly, when receiving the RM cell of the ABR feedback control loop, the ATM level 121 of the ATM transmitting terminal 12 replaces the value thereof with the 'last_ER' value, and transmits the replaced value to the TCP level 122 (S1).

The TCP level 122 of the ATM transmitting terminal 12 receiving the 'last_ER' value computes the allowed window size (awnd). Here, the TCP level 122 of the ATM transmitting terminal 12 sets 'cwnd' to be '1' at an initial stage (S2). The decision of the allowed window size (awnd) is driven when the acknowledgement (ACK) signal is received (S3). The 'cwnd' value is computed by Expressions (2) and (3) (S4).

In addition, the allowed window size (awnd) is computed as shown in Expression (1), and a transmittable amount thereof at that point is transmitted to the receiving side (S5).

After computing the allowed window size (awnd), the conventional TCP algorithm is applied as it is. Here, the allowed window size (awnd) indicates the right edge of the sliding window at the present point. The transmittable amount is a difference between the 'awnd' value and an amount of the data which have been lastly transmitted (namely, the amount of data which do not receive the acknowledgement (ACK) signal).

Here, the transmission can be performed only when the value is positive.

Tables 1 and 2 as shown below are simulation results for measuring the TCP performance when the algorithm according to the present invention is applied. The throughput (Mbps) and the ratio of retransmission (%) are computed by using a performance parameter of the TCP. The throughput is computed by dividing transmission amount by transmission time, and the ratio of retransmission is computed by dividing the number of the retransmitted packets by the number of the transmitted packets.

The simulation is carried out in a state where five users of a file transfer protocol (FTP) operated over the ABR service and n users of an on-off constant bit rate (CBR) share a link of 150Mbps. In order to presume the local area network (LAN) and the wide area network (WAN) environment, in the length of the links (l_1, l_2, l_3), the simulation is performed in regard to the lengths of 1Km, 100Km, 1Km and 0.1Km, 1Km, and 0.1Km, respectively.

Parameters used for the simulation will now be listed.

Link capacity = 150Mbps

Link buffer = 1,000 cells (for on-off CBR users), 2,500 cells (for FTP users)

On-off CBR source on time = 84ms, off time = 84ms

TCP maximum segment size (MSS) = 9,140bytes

TCP timer granularity = 50ms

TCP maximum window size = 20 segments = 182,800bytes

User buffer size = 1,000,000 cells

ABR Nrm (number of cells between forward RM cells) = 32

Peak cell rate (PCR) = 150Mbps

Minimum cell rate (MCR) = 0.1Mbps

Initial cell rate (ICR) = 5Mbps

Rate Increase Factor (RIF) = 1

Rate Decrease Factor (RDF) = 1

Transient buffer exposure (TBE) = 512 cells

In order to evaluate performance when only the TCP employs a fixed bandwidth, it is presumed that a background traffic does not exist. In addition, for the states where a burstiness of the network is large and small, one 100Mbps on-off CBR user and ten 10Mbps users are presumed. The five 10Mbps users are presumed to observe the operation of an algorithm suggested when the resources of the network are plentiful.

In the respective network states, the simulation is performed by varying the safety_factor(s). The following Tables show the results of the simulation.

Table 1. Simulation result in wide area network

Background Traffic	Performance Parameter	Before Variation	After Variation					
			s= 0.2	s= 0.3	s= 0.4	s= 0.5	s= 0.6	s= 0.7
0Mpbs	Processing Ability	92.6	126.0	126.0	128.8	128.8	129.2	121.8
	Ratio of Retransmission	14.4	2.1	2.1	0.8	0.5	0.5	3.7
100Mbps*1	Processing Ability	67.4	82.3	82.7	83.3	81.6	78.7	75.5
	Ratio of Retransmission	9.7	4.5	1.0	2.2	3.4	6.2	7.3
10Mbps*10	Processing Ability	65.6	85.5	86.0	83.9	82.0	77.5	74.1

	Ratio of Retransmission	10.9	1.7	1.0	2.2	3.4	6.2	8.4
10Mbps*5	Processing Ability	75.6	105.9	107.0	107.6	105.8	100.5	94.4
	Ratio of Retransmission	15.0	1.8	1.3	0.8	1.7	4.4	7.4

Table 2. Simulation result in local area network

Background Traffic	Performance Parameter	Before Variation	After Variation						
			s=0.2	s=0.3	s=0.4	s=0.5	s=0.6	s=0.7	s=0.8
0Mpbs	Processing Ability	94.2	91.4	98.2	104.1	114.3	122.4	121.8	115.9
	Ratio of Retransmission	14.0	14.2	12.8	11.2	7.1	3.7	3.8	6.3
100Mbps*1	Processing Ability	67.4	67.3	70.0	72.6	75.1	76.6	74.9	73.2
	Ratio of Retransmission	10.3	11.1	11.2	10.4	8.9	7.5	8.0	8.9

10Mbps*10	Processing Ability	65.8	65.8	70.5	74.9	79.4	78.6	75.6	73.5
	Ratio of Retransmission	10.6	12.2	11.0	8.3	5.3	5.7	7.7	9.1
10Mbps*5	Processing Ability	76.6	78.3	82.2	89.2	98.3	101.4	96.8	92.8
	Ratio of Retransmission	14.8	13.5	12.9	10.3	5.8	4.0	6.3	8.4

As shown in the above Tables, the TCP performance is improved by using the suggested method in every background traffic. The window size of the conventional TCP increases regardless of the network state, and repeats the information loss, the resultant retransmission and the increase of the window size. However, when the algorithm in accordance with the present invention is applied, the window size is flexibly varied according to the network state.

In regard to performance of the TCP, in the case that the safety_factor(s) is approximately to 0.5, the throughput is considerably improved and the ratio of retransmission is reduced in both the local area network and the wide area network. As a result, in addition to improvement of the throughput, the ratio of retransmission is decreased, thereby reducing unnecessary consumption of the network resources.

That is to say, when the safety_factor(s) is 0.5, the throughput increases by 10.27% to 28.3 according to the network states, and the ratio of retransmission decreases remarkably.

It is thus confirmed that the TCP performance is considerably improved by using the TCP window size control algorithm suggested for the TCP service over the ABR service in accordance with the present invention.

For reference, the technical matters of the present invention have been published in 'The Korean Communication Institute' on November 14, 1998, entitled by 'Performance improvement of TCP over ATM by using RM cell information'.

As discussed earlier, in accordance with the present invention, the cells transmitted pursuant to the ER value are rarely dropped or tagged by the switch algorithm, thereby reducing the ratio of retransmission.

As the present invention may be embodied in several forms without departing from the spirit or essential characteristics thereof, it should also be understood that the above-described embodiment is not limited by any of the details of the foregoing description, unless otherwise specified, but rather should be construed broadly within its spirit and scope as defined in the appended claims, and therefore all changes and modifications that fall within the meets and bounds of the claims, or equivalences of such meets and bounds are therefore intended to be embraced by the appended claims.

WHAT IS CLAIMED IS:

1. A method for controlling a transmission control protocol window size in an asynchronous transfer mode network, wherein a window size is computed by using congestion information of a network during data transmission from a transmitting side ATM terminal to a receiving side ATM terminal, an explicit rate value in a resource management cell of an ATM level being used as the congestion information.

2. The method according to claim 1, wherein the explicit rate value stores a minimum value of throughputs, which each node of the network can receive, in the network resource management cell.

3. The method according to claim 1, wherein the window size is computed by the Expression wherein,

window size = MIN [credit, cwnd],

('credit' is an amount of data which the transmission control protocol receiving side can receive, 'cwnd' is a congestion window, cwnd = transmission control protocol throughput * estimated_RTT * safety_factor),

'estimated_RTT' is an estimated round trip time of the packet,

'safety_factor(s)' is a numerical value compensating for variations in network states and RTT,

$$\text{TCP throughput} = \text{last\_ER} * \frac{48}{53} * \frac{31}{32} * \frac{TCP\_MSS}{TCP\_MSS + 56 bytes}$$

'last_ER' is an ER value in the currently-received RM cell, and

'TCP_MSS' is a maximum segment size of the transmission control protocol level.

4. A method for controlling a transmission control protocol

window size in an asynchronous transfer mode network, comprising:

a step for an ATM transmitting terminal to receive a resource management cell;

a step for transmitting an explicit rate value in the received resource management cell to a transmission control protocol level in the ATM transmitting terminal;

a step for setting a congestion window to be '1', when the explicit rate value is received;

a step for computing the congestion window, when an acknowledgment signal is received from an ATM receiving terminal; and

a step for computing a window size, when the congestion window value is computed, and for transmitting a data to the ATM receiving terminal according to the computed size.

5. The method according to claim 4, wherein the congestion window is computed by the Expression wherein,

congestion window = transmission control protocol throughput * estimated_RTT * safety_factor

('estimated_RTT' is an estimated round trip time of the packet, and 'safety_factor(s)' is a numerical value compensating for variations in network states and RTT).

6. The method according to claim 5, wherein the transmission control protocol throughput is computed by the Expression wherein,

$$\text{TCP throughput} = \text{last\_ER} * \frac{48}{53} * \frac{31}{32} * \frac{TCP\_MSS}{TCP\_MSS + 56bytes}$$

('last_ER' is an ER value in the currently-received RM cell, and

'TCP_MSS' is a maximum segment size of the transmission control protocol level).

7. The method according to claim 4, wherein the window size is computed by the Expression wherein,

window size = MIN [credit, cwnd],

('credit' is an amount of data which the transmission control protocol receiving side can receive, and 'cwnd' is a congestion window).

ABSTRACT OF THE DISCLOSURE

The present invention relates to a method for controlling a transmission control protocol window size in an asynchronous transfer mode network which determines a TCP congestion window size by using an explicit rate value in a resource management cell. According to the present invention, cells transmitted pursuant to the explicit rate value are rarely dropped or tagged by a switch algorithm, thereby reducing a ratio of retransmission.

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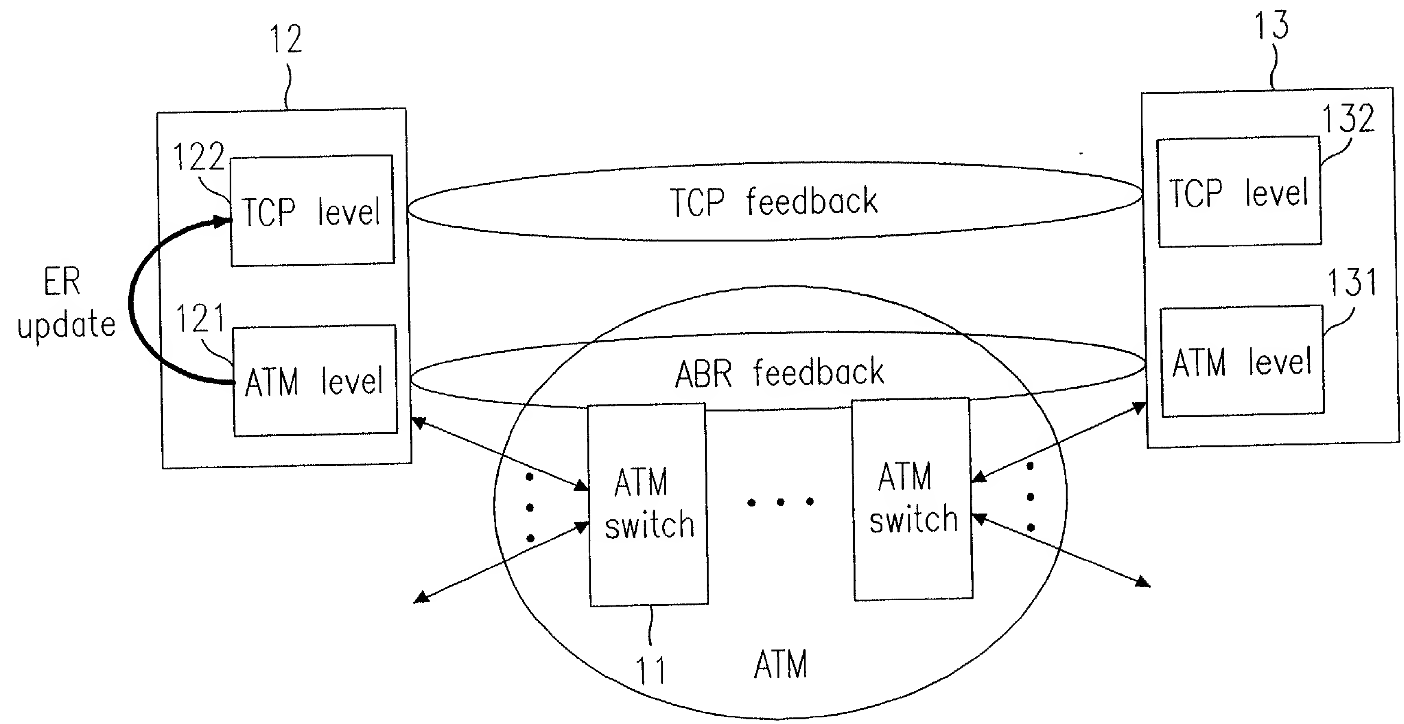
12
122
TCP level
121
ATM level
ER
update
TCP feedback
ABR feedback
ATM
switch
ATM
switch
11
ATM
13
132
TCP level
131
ATM level

Fig.1

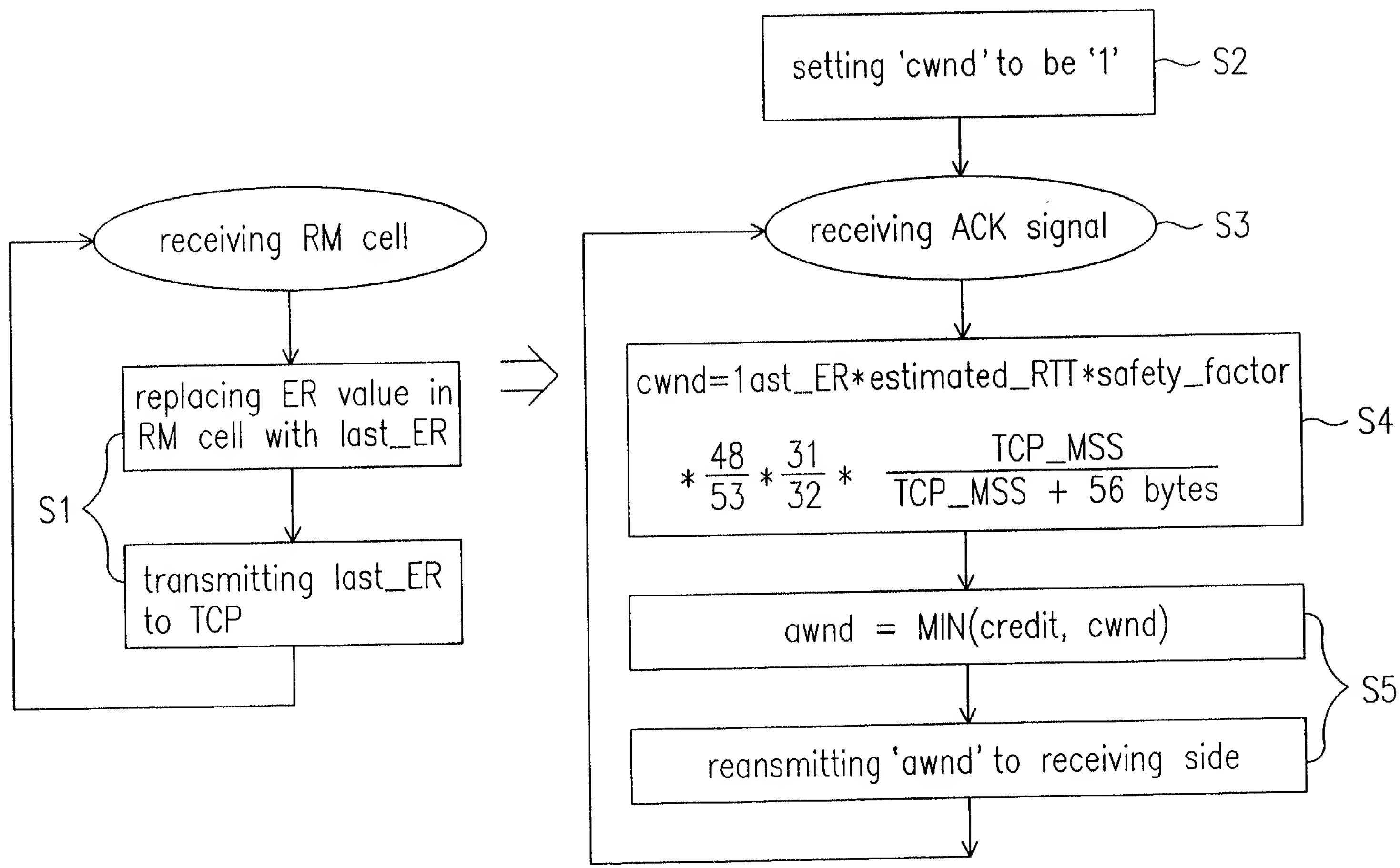
receiving RM cell
replacing ER value in RM cell with last_ER
transmitting last_ER to TCP
S1
setting 'cwnd' to be '1'
S2
receiving ACK signal
S3
cwnd=1ast_ER*estimated_RTT*safety_factor
$* \frac{48}{53} * \frac{31}{32} * \frac{TCP\_MSS}{TCP\_MSS + 56 \text{ bytes}}$
S4
awnd = MIN(credit, cwnd)
reansmitting 'awnd' to receiving side
S5

Fig.2

pplications

MERCHANT & GOULD

United States Patent Application

STRUCTIONS

COMBINED DECLARATION AND POWER OF ATTORNEY

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TLE of invention

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The specification of which

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as application serial no. ______

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k a or b

a. ☐ no such applications have been filed.

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COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	DATE OF ISSUE (day, month, year)
Korea	99-17310	14/05/1999	
ALL FOREIGN APPLICATIONS, IF ANY, FILED BEFORE THE PRIORITY APPLICATION(S)			
COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	DATE OF ISSUE (day, month, year)

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Gresens, John J.	Reg. No. 33,112	Schmidt, Cecil C.	Reg. No. 20,566		
Hamre, Curtis B.	Reg. No. 29,165	Schuman, Mark D.	Reg. No. 31,197		

I hereby authorize them to act and rely on instructions from and communicate directly with the person/assignee/attorney/firm/organization/who/which first sends/sent this case to them and by whom/which I hereby declare that I have consented after full disclosure to be represented unless/until I instruct Merchant, Gould to the contrary.

Please direct all correspondence in this case to Merchant, Gould, Smith, Edell, Welter & Schmidt at the address indicated below (or if no address is specified, the first address):

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Insert FULL name(s) AND address(es) of actual inventor(s)

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Each inventor must sign & date

Note No legalization or other witness required

SIGNATURE OF INVENTOR 201	SIGNATURE OF INVENTOR 202	SIGNATURE OF INVENTOR 203
Jae Il Jung	Sung Won Kang	Youngsoo Seo
DATE Oct. 22, 1999	DATE Oct. 22, 1999	DATE Oct. 22, 1999

For Additional Inventors:

☐ Check box and attach sheet with same information, including date and signature.

Revised 11/1/92